AUTOMATION OF PRODUCTION

UDC 666.1.033

AN AUTOMATED PRODUCTION LINE FOR GENERAL-PURPOSE LAMP BULBS BASED ON THE RIBBON TECHNOLOGY

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Translated from Steklo i Keramika, No. 8, pp. 9 – 11, August, 2004.

The performance of an automated line for electric bulb production at the V.A.V.S. Electric Lamp Works (Moscow Region) has been considered. The implementation of automatic control systems to a great extent determines the high quality of the finished product.

The Electric Lamp Works of the V.A.V.S. Holdings in 2003 installed an automated line for bulb production as a consequence of joint research of the company specialists and the Sevzapmontazhavtomatika Engineering Bureau.

The automatic control system of the process is based on the Modbus Plus real-time network. The visualization system and the databases are based on the Ethernet. This project has been designed as an integrated technological complex, from glass melting to the finished product.

The line efficiency depends on the ribbon-machine (AKV-1) efficiency and amounts to 1150 bulbs/min. At present the line produces 34 million bulbs for incandescent lamps monthly.

Automatic system for controlling glass melt temperatures in the working channel and the ribbon-process feeder. In order to bring the thermal and chemical glass melt parameters to the prescribed standard before producing bulbs, an original feeder (the Corning feeder) is used in the ribbon-process. The total length of the feeder from the site of its connection with the furnace to the bowl axis is 8 m 91.5 cm. This feeder consists of four individual sections, each of which is actually a mini-feeder. Each section is a refractory structure with its own heating, cooling, temperature monitoring, and control system.

The glass melt heating system is located at the gas-mixing station (GMS) that forms part of the technological ribbon-process complex. The standard mixer of this particular GMS is based on the Venturi principle with 0-regulators of gas pressure of original design.

The cooling system is based on supplying fan air under the roof space of the feeder section. The air penetrates via refractory inlets into the feeder from the lateral walls, fanning the lower part of the roof, and exits via the ventilation openings in the roof. The air flow is controlled with a throttle, and the position of the lids of the roof opening is synchronically operated using a mechanical coupling.

The heating and cooling subsystems of each control zones are mechanically related.

An original multielement temperature control system has been designed by Corning for this particular feeder using original imported electronic regulators.

The ribbon-process technology that had been purchased by the USSR was reproduced by the Elektrotekhnik Works in Beshkek adding their own automated control system. In particular, the automatization of the feeder was performed by electric lamp factories using local regulators Miniterm-400 (LISMA, city of Saransk) and Remikont (Milisaiskii Electric Lamp Works).

These control systems satisfactorily support temperature parameters in a standard regime, mainly the glass melt output. However, in the case of disturbances, such as changes in the glass melt output, the regulator was not able to maintain the temperature. A remote control operator had to select a new temperature regime and then switched on the automatic control mode.

Fundamental difficulties of glass melt temperature control due to time delays in thermal processes. The above-described behavior of the automatic control contour for the glass melt temperature inside the feeder is typical of solving this problem based on a PID regulator.

The dependence of glass melt temperature on controlling effects (heating and cooling) due to the substantial inertia of heat exchange are processes with a time lag or delay. Thus, the more intense heating of the glass melt surface is accom-

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0361-7610/04/0708-0252

panied by an increase in temperature with a perceptible time lag, the value of this lag being different for different layers of the melt.

The main difficulties in a system with time lags are related to the fact that the information arriving with a delay disturbs the stability of the system. In our example with glass melt heating, the PID regulator that has not received a response with respect to changing glass melt temperature intensifies heating, which leads to overheating of the glass melt.

In order to decrease the instability risk, the PID control of processes with time lags should maintain intensifying process at the lowest possible level. Therefore, PID regulators are incapable of automatically compensating the emerging disturbances.

The problems of time-lag system control were solved in 1957 by creating a regulator that includes a system model named the Smith extrapolator [1]. The authors successfully isolated the main idea of the Smith regulator: the "old" controlling signals for the processes with time delay should be stored and correct the current controlling signal. When Otto Smith proposed this idea, it was difficult to produce such a regulator, since only analogous technology was then available. Storing data is a trivial problem for digital technology.

Controlling glass melt temperatures in the ribbon feeder based on the Smith extrapolator principles. We have solved the problem of integrated automation of the ribbon-process feeder on a TSX Premium controller integrated in the real-time industrial network of the bulb production division. The feeder operator can see the entire technological process on an APM display.

The automatic regulation of glass melt temperature is based on a system of connected contours. The inferior subordinated regulation contours are stabilizing PID contours based on fast-changing parameters. Such parameter selected for the feeder is the pressure of the gas-air mixture in front of the burners. Since cooling is rigidly related to the heating process (a mechanical coupling), it is possible to control the thermal process based on the pressure of the mixture in front of the burners in the regulation zone.

These PID regulators have been operating since the first day of the feeder operation. The remote control of the thermal processes performed by the feeder operator is reduced to modifying the pressure target value for the regulator of a particular zone. Clearly, the correction of the automatic setting occurs without switching off the automated mode of the stabilization control contour.

For the first 2 month the system operated in this mode, while the technological data were stored in the database. Beside the technological parameters, such as temperature, pressure of the mixture, cooling air flow rate, all controlling actions of the operator were registered as well.

Only after the technological database was analyzed did it become possible to construct programs for the "superior" controlling automatic contours for the regulation of the feeder temperature.

The automated temperature regime of the feeder controls the settings for the "inferior" automatic subsystems by correcting the pressure of the gas-air mixture in front of the burners. The operator has to set the temperature distribution for the feeder zones. The temperatures set are based on the values of glass melt temperature near its surface.

The algorithm of the glass melt temperature control contour is based on the formulas of a generalized discrete regulator from the paper of G. Ollsona and D. Piani. The algorithm is implemented in a simplified and transformed form (for convenience in selecting regulation coefficients) in the controller programming system produced by the Schneider Electric PL7 Pro.

The automatic regulation of temperatures makes it homogeneous. The admissible discrepancy between the temperatures of the surface and bottom layers in the conditioning zone and the bowl zone does not exceed a few tenths of a degree on the Centigrade scale.

Another important result of the automatic control system is the possibility of automatic control of the readjustment of the feeder. Thus, changing to a different type of the bulb, it is sufficient for the operator to set the next temperature distribution target for the feeder. The transitional processes in the automatic regime are smooth and occur within the technological rules for the feeder readjustment (for instance, 6 h). In practice, the time of readjustment of the production line for a new type of bulb can be shortened.

Use of the principles of controlling thermal processes of the feeder for the working channel. The technology of the working channel is analogous to the feeder section. However, there are certain specifics in controlling glass melt temperatures in the working channel:

– the gas-mixing station designed by the Giprosteklo JSC is based on up-to-dates gas equipment produced by the Kromshcroeder firm; this GMS design has been tested and is capable of replacing the obsolete GMS of the ribbon-feeder;

– the mechanical coupling between the processes of heating and cooling of glass melt has been eliminated; the setting of interrelation of these processes has become more flexible, which expands the dynamic range of the glass-melt temperature regulator in the working channel.

The automatic control of the working channel temperature is based on the same principles as in the feeder: a system of related control contours is used. The efficient control of the glass melt temperature in the working channel has a significant effect on its preparation for molding: a constant glass melt temperature stabilizes the work of the whole feeder and smooths temperature disturbances originating from the glass-melting furnace.

Modernization of the ribbon-machine automatics. The bulb-blowing AKV-1 automatic machine (otherwise known as the ribbon-machine) is produced under license at the Elektrotekhnik JSC in Beshkek.

The spectacle-plate conveyer forms a glass ribbon, the blow-head conveyor blows the preforms, and the form conveyer completes the formation process. The velocities of all

three conveyors are rigidly synchronized (mechanically): the main electric drive controls the whole machine. This drive used to be a direct-current drive, which was a weak spot in the ribbon-machine: the precision of maintaining the velocity was 2% of the rated value, which had a significant effect on the bulb quality.

At present the drive of the AKV-1 automatic machine is controlled by means of frequency converters Altivar-58, series F (high-precision control of the drive velocity). Despite the high reliability of Altivar-58, the system is equipped with one main frequency converter and another reserve one. The engine cylinder velocity sensors are built-in Euro-Drive encoders with a high measuring precision. The frequency converter has a built-in PID contour for automatically maintaining a preset velocity.

The drive control is implemented using a TXS Micro controller included in a distributed control system of the production division. The machine velocity is set either locally, i.e., directly from the frequency converter control panel installed near the machine, or in the remote mode by the ribbon-machine operator (or Magelis terminal) from the operator’s room. The system provides for smooth speeding up of the machine and its smooth slowing down without the participation of the operator.

The emergency-prevention alarm system regarding the drive errors has been intensified, and the main technological parameters of the drive are stored in the database. The main drive has two-level protection from overload: the overload-protection function built in the frequency converter and the system for an emergency switch-off of the drive in the controller.

The replacement of the direct-current drive used in the Ribbon-400 glass-forming machines by Altivar-58F has made it possible to increase the precision of the conveyor velocities from 2.0 to 0.1% of the rated value. This is a significant improvement for the given machine.

Another important function of the automatic control system of the ribbon-machine is the control of temperature regimes in the zones of the blow-head and spectacle-plate conveyers. These parameters are very important for the formation technology, since they affect the quality of bulbs.

In the ribbon-machines produced at the Elektrotekhnik JSC, the standard PV-16 pyrometers initially designed for monitoring temperature in the zones of these conveyers have been replaced by up-to-date pyrometers produced by the Raytek company. This has made it possible to implement the automatic regulation of temperature, which resulted in the high quality of bulbs manufactured by the Company.

REFERENCES

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